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A Thermoelectric Refrigerator Using Arduino

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ABSTRACT

Refrigerator and air conditioners are the most energy consuming home appliances and for this reason many researchers had performed work to enhance performance of the refrigeration systems. Most of the research work done so far deals with an objective of low energy consumption and refrigeration effect enhancement. Thermoelectric refrigeration is one of the techniques used for producing refrigeration effect. Thermoelectric devices are developed based on Peltier and Seeback effect which has experienced a major advances and developments in recent years. The coefficient of performance of the thermoelectric refrigeration is less when it is used alone, hence thermoelectric refrigeration is often used with other methods of refrigeration. This paper presents a review of some work been done on the thermoelectric refrigeration over the years. Some of the research and development work carried out by different researchers on TER system has been thoroughly reviewed in this paper. The study envelopes the various applications of TER system and development of devices. This paper summarizes the advancement in thermoelectric refrigeration, thermoelectric materials, design methodologies, application in domestic appliances and performance enhancement techniques based on the literature.

Keywords: Refrigerator; Thermoelectric refrigeration; Thermoelectric materials; Design methodologies; Applications.

1. Introduction

Conventional cooling systems such as those used in refrigerators utilize acompressor and a working fluid to transfer heat. Thermal energy is absorbed and released as the working Fluid undergoes expansion and compression and changes phase from liquid to vapor and back, respectively. Semiconductor thermoelectric coolers (also known as Peltier coolers) offer several advantages over conventional systems. They are entirely solid-state devices, with no moving parts; this makes them rugged, reliable, and quiet [1-4]. They use no ozone depleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to conventional refrigeration. They can be extremely compact, much more so than compressor-based systems. Precise temperature control (< ± 0.1°C) can be achieved with Peltier coolers.

However, their efficiency is low compared to conventional refrigerators. Thus, they are used in applications where their unique advantages outweigh their low efficiency. Although some large-scale applications have been considered (on submarines and surface vessels), Peltier coolers are generally used in applications where small size is needed and the cooling demands are not too great, such as for cooling electronic components (Astrain and Vian, 2005). Objective of this project is to design thermoelectric Refrigerator Utilize Peltier effect to refrigerate and maintain a specified temperature, perform temperaturecontrol in the range 5°C to 35°C. Interior cooled volume of 5 Litre and Retention for next half hour [5-7].

2. Literature Survey

Since the onset of invention of thermoelectricity came into existence, much research has been directed towards the development of semiconductor materials. The improvisations made into the different materials aimed at increasing the valueof ZT so as to improve the performance of TE modules. In 1993, Hicks and Dresselhaus proposed that low dimensionality in materials could result in enhanced electronic density of states near the Fermi energy. This could

eventually lead to larger Seebeck coefficients, and it was found that in nanostructured materials boundary scattering can affect phonons more than electrons. Mahan has also described the characteristics of good TE materials agreeing with Slack that the candidate material is typically a narrow-band gap semiconductor [Eg=10 (kBT), or 0.25 eV at 300 K]. Results from Sales et al., and Fleurial et al., show high ZT values (the common figure of merit for comparing different TE materials) at elevated temperatures in LaFe3CoSb12 and CeFe3CoSb12 for both p-type and n-type specimens. Many researchers including Tada et al., around the globe have reviewed the possibility of utilizing the heat transfer effect due to forced convection using porous thermoelectric converter combined with a flow system. Basic features of the porous TE cooler assumed thefigure-of-merit of the porous TE elements to be ZTo = 1, which is the most likely performance for future TE materials. Other relevant physical properties are assumed to be the same as for Bi2Te3 based TE materials [8-10].

3. Proposed System

Thermoelectricity was discovered and developed in 1820-1920 in Western Europe, with much of work centered in Berlin. The first important discovery related to thermoelectricity occurred in 1823.

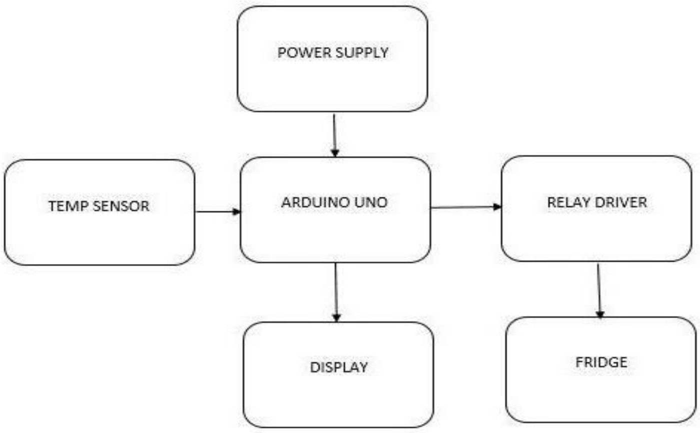

Figure 1. Block Diagram

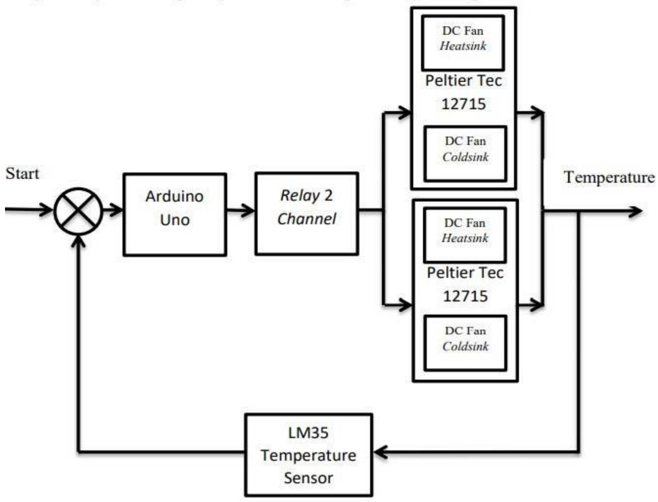

Figure 2. System Architecture

German scientist Thomas Seebeck found that a circuit made from two dissimilar metals and junctions of the same kept at two different temperatures, produces thermoelectric force which is responsible for flow of the current

through module. Now this invention is known as Seebeck effect. In 1834, a French watchmaker and physicist, Jean Charles Athanase Peltier invented thermoelectric cooling effect also known as Peltier effect. Peltier stated that electric current flows through two dissimilar metals would produce heating and cooling at the junctions. The true nature of Peltier effect was made clear by Emil Lenz in 1838, Lenz demonstrated that water could be frozen when placed on a bismuth-antimony junction by passage of an electric current through the junction. He also observed that if the current was reversed the ice could be melted. In 1909 and 1911 Altenkirch give the basic theory of thermoelectric. His work explained that thermoelectric cooling materials needed to have high Seebeck coefficients, good electrical conductivity to minimize Joule heating, and low thermal conductivity to reduce heat transfer from junctions to junctions. In 1949 Loffe developed theory of semiconductors thermo-elements and in 1954 Goldsmid and Douglas demonstrated that cooling from ordinary ambient temperatures down to below 0°C was possible.

4. Basic Principles of Thermoelectric Device

In 1821, Thomas Seebeck found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals, if the junctions of the metals were maintained at two different temperatures. Thermoelectric power supply generators are based on the Seebeck effect which is based on voltage generation along a conductor subjected to a gradient of temperature. When a temperature gradient is applied to a conductor, an electromotive force is produced. The voltage difference generated is proportional to the temperature difference across the thermoelectric module between the two junctions, the hot and the cold one.

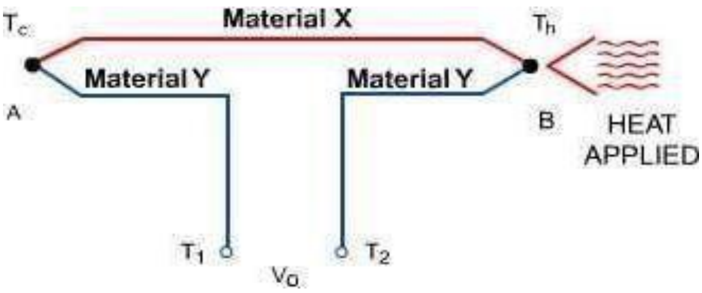

Figure 3. Seebeck Effect

Specifications

Microcontroller	ATmega328
Clock Speed	16MHz
Operating Voltage	5V
Maximum supply Voltage (not recommended)	20V
Supply Voltage (recommended)	7-12V
Analog Input Pins	6
Digital Input/Output Pins	14
DC Current per Input/Output Pin	40mA
DC Current in 3.3V Pin	50mA
SRAM	2KB
EEPROM	1KB
Flash Memory	32KB of which 0.5KB used by boot loader

Development of Thermoelectric Device

The thermoelectric cooler is a cooling device based on TER principle which has been widely used in military, aerospace, instrument, and industrial or commercial products, as a cooling device for specific purposes.

The schematic of the thermoelectric cooler is shown in below fig. Huang et.al.developed a system design method of TE cooler in their study which utilizes the performance curve of the TE module.

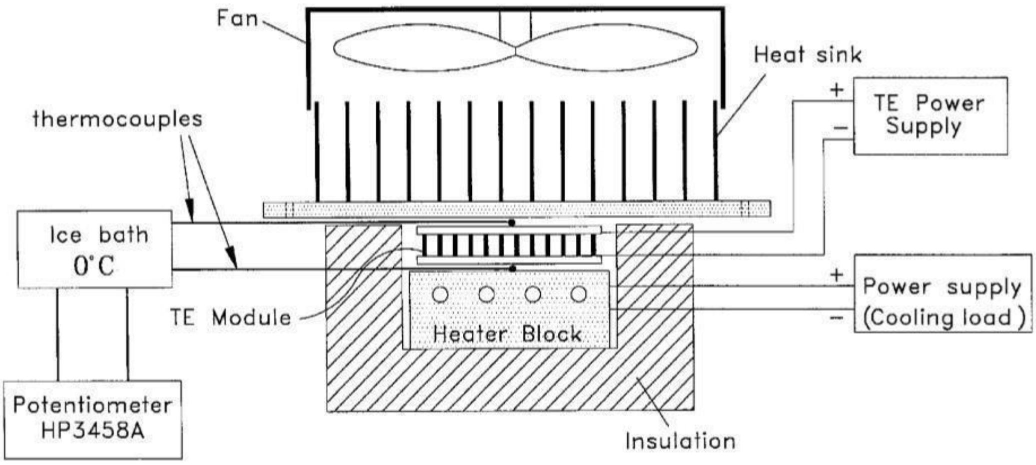

Figure 4. Thermo Electric Cooler

Jiajitsawat investigated theoretically & experimentally the effect of combination of TER system & DEAC system. For this he had fabricate a portable hybrid thermoelectric-direct evaporative air cooling system and tested. The schematic of the prototype is shown in Figure below. The operating principle of the prototype is the water in the container for further improvement of the air cooling capacity.

Experiment was carried out in three ways: Fan operation, Direct evaporative air-cooling operation & TER-DEAC operation. When DEAC system is in active, the cooling performance of the prototype increases by 20% & is up to 30% with higher fan speed. The results of TE installation can improve the cooling performance of the DEAC system by 10% and is up to 20% with higher fan speed. Therefore, the implementation of TE to DEAC seems to be reliable and possible for commercial application.

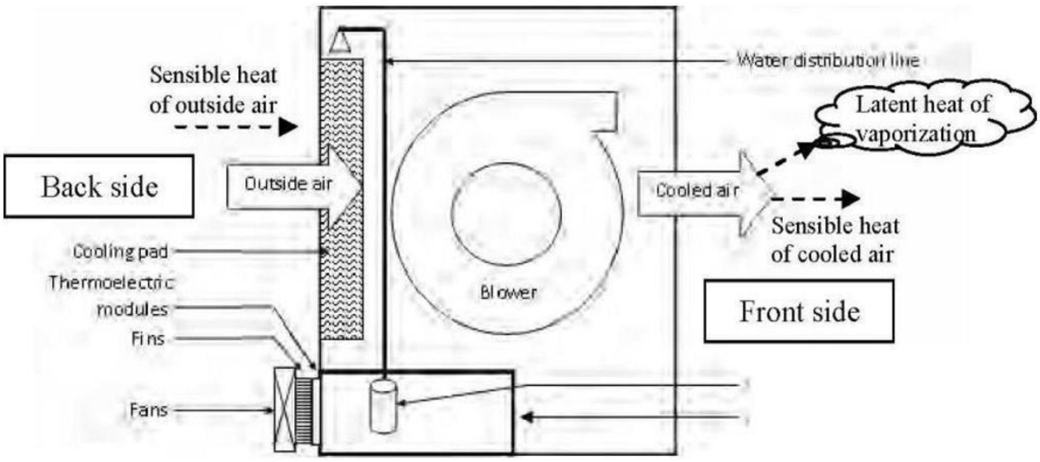

Figure 5. Combined TE Direct Evaporative Air-cooler

5. Conclusion

The objective project is to achieve the long term cooling in case of power failure for refrigerator. A TER Cooling system is has been designed and developed to provide active cooling with help of single stage 12 V TE module is used to provide adequate cooling. First the cooling load calculations for this TER compartment considered under

study were presented. Simulation tests in laboratory have validated the theoretical design parameters and established the feasibility of providing cooling with single stage thermoelectric cooler was tested in the environmental chamber. As TER not available in open market which we can retain cooling at case of power outage due to high current carrying capacity. The retention time achieved was 52 min with the designed module in this project. In order to achieve the higher retention time, another alternative was incorporate. This consists the additional heater on heat sink. The highest retention time achieved was 57 mins.

Declarations

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This study did not receive any grant from funding agencies in the public or not-for-profit sectors.

Competing Interests Statement

The authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

All authors took part in literature review, research, and manuscript writing equally.

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